JC14 Rec'd PCT/PTO 11 JUL 2001

FORM PTO-1390 U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NO. PHJ 99-024
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S. Application No. (if known, see 37 CFR 1.5) 09/889090
INTERNATIONAL APPLICATION NO. PCT/EP00/11250	INTERNATIONAL FILING DATE November 10, 2000	PRIORITY DATE CLAIMED November 12, 1999

TITLE OF INVENTION
LIQUID CRYSTAL DISPLAY APPARATUS

APPLICANT(S) FOR DO/EO/US
Satoshi Hirano; Masaru Yasui; Takeo Kamiya (deceased)

Applicant(s) herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.

2. [ ] This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.

3. [ ] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).

4. [ ] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. [ ] copy of the International Application as filed (35 U.S.C. 371 (c)(2))
   a. [ ] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).

6. [X] A translation of the International Application into English (35 U.S.C. 371(c)(2))

7. [ ] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.

8. [ ] A translation of the amendment to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).

9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98.

12. [X] An assignment document for recording. A separate cover sheet is compliance with 37 C.F.R. 3.28 and 3.31 is included.

13. [X] A FIRST preliminary amendment.
    [ ] A SECOND OR SUBSEQUENT preliminary amendment.

14. [ ] A substitute specification.

15. [ ] A change of power of attorney and/or address letter.

16. [X] Other items or information:

    4 sheets of Drawings
    X Authorization Pursuant to 37 CFR § 1.136(a)(3) and to Charge Deposit Account
    X 2 Powers of Attorney by Akira Kamiya dated April 18, 2001

CERTIFICATE OF MAILING

[X] Express Mail Mailing Label No. EL686948728US
Date of Deposit July 11, 2001

I hereby certify that this paper and fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231.

Elissa DeLuccy
Typed Name

Elissa DeLuccy
Signature

JC18 Rec'd PCT/PTO 11 JUL 2001

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5) 09/889090	INTERNATIONAL APPLICATION NO. PCT/IB	ATTORNEY'S DOCKET NUMBER PH

17 [X] The following fees are submitted:		CALCULATIONS (PTO USE ONLY)
BASIC NATIONAL FEE (37 C.F.R. 1.492(A)(1)-(5)):		
Search Report has been prepared by the EPO or JPO	$860.00	
International preliminary-examination fee paid to USPTO (37 C.F.R. 1.482)	$690.00	
No international preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but international search fee paid to USPTO (37 C.F.R. 1.445(a)(2)	$750.00	
Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2)) paid to USPTO	$970.00	
International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)	$ 96.00	
ENTER APPROPRIATE BASIC FEE AMOUNT =		$ 860.00

Surcharge of $130.00 for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)).				$	
CLAIMS	NUMBER FILED		NUMBER EXTRA	RATE	
Total Claims	6 - 20 =			X $ 18.00	$
Independent claims	1 - 3 =			X $ 80.00	$
MULTIPLE DEPENDENT CLAIMS (if applicable)				+ $270.00	$
TOTAL OF ABOVE CALCULATIONS =					$ 860.00
Reductions by 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 C.F.R. 1.9, 1.27, 1.28)					$
SUBTOTAL =					$ 860.00
Processing fee of $130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 C.F.R. 1.492(f)). +					$
TOTAL NATIONAL FEE =					$ 860.00
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28,3.31). $40.00 per property +					$ 40.00
TOTAL FEES ENCLOSED =					$ 900.00
				Amount to be refunded	$
				charged	$

a. [ ] A check in the amount $_____ to cover the above fees is enclosed.

b. [X] Please charge my Deposit Account No. 14-1270 in the amount of $900.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fee, with the exception of the Base Issue Fee, which may be required, or credit any overpayment to Deposit Account No. 14-1270. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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(SIGNATURE)

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of Atty. Docket

HIRANO ET AL PHJ 99-024

Serial No. Group Art Unit

Filed: CONCURRENTLY Ex.

Title: LIQUID CRYSTAL DISPLAY APPARATUS

Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Sir:

Prior to calculation of the filing fee and examination, please amend the above-identified application as follows:

IN THE CLAIMS

Please amend the claim 6 as follows:

6. (amended) A liquid crystal displaying apparatus according to claim 1 characterized in that said digital input values Ri, Gi and Bi for said red, green and blue sub-pixels obtained from said input color image are converted respectively into RI, GI and BI as values having a dimension of luminance, and in that a relationship of RI:GI:BI = (RO+WO):(GO+WO):(BO+WO) is satisfied when luminance values for said red sub-pixel, said green sub-pixel, said blue sub-pixel and said luminance-enhancing sub-pixel are represented by RO, GO, BO and WO, respectively.

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REMARKS

The foregoing Preliminary Amendment to claim 6 was made solely to avoid filing the claims in the multiple dependant form so as to avoid the additional filing fee.

The claims were not amended in order to address issues of patentability and Applicants respectfully reserve all rights they may have under the Doctrine of Equivalents. Applicants furthermore reserve their right to reintroduce subject matter deleted herein at a later time during the prosecution of this application or continuing applications.

Respectfully submitted,

By 
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Attorney
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APPENDIX

Amended Claim

6. (amended) A liquid crystal displaying apparatus according to ~~any one of claims 1 to 5~~ claim 1 characterized in that said digital input values Ri, Gi and Bi for said red, green and blue sub-pixels obtained from said input color image are converted respectively into RI, GI and BI as values having a dimension of luminance, and in that a relationship of RI:GI:BI = (RO+WO):(GO+WO):(BO+WO) is satisfied when luminance values for said red sub-pixel, said green sub-pixel, said blue sub-pixel and said luminance-enhancing sub-pixel are represented by RO, GO, BO and WO, respectively.

Liquid crystal display apparatus

This invention relates to a liquid crystal display apparatus capable of displaying color images.

In recent years, liquid crystal display apparatuses capable of displaying color images have been widely used as display apparatuses, for example, for personal computers, video cameras and car navigation systems.

A Liquid crystal display apparatus of the RGBW type (hereinafter referred to as "an RGBW-type liquid crystal display apparatus"), on which a transparent filter (W) is arranged in addition to an RGB filter of the conventional RGB type, has been proposed in Japanese Patent Application Laid-open No.10998/1998 as a method for improving luminance of pixels of a liquid crystal panel of such liquid crystal display apparatus.

However, even if the transparent filter is added in order to improve luminance, the ratio of red, blue and green of the original image will be changed, since the white color is mixed in all display colors. As a result, the color purity (color saturation) of a displayed image is reduced with respect to the original image, so that a chromaticity will be changed, in particular, in halftones.

Accordingly, an object of the invention is to provide an RGBW-type liquid crystal display apparatus in which a chromaticity is not changed even in halftones, by adding a white component to a red component, a green component and a blue component of an original input image for improving luminance thereof and thereafter further converting the ratio of these red, green and blue components after the addition of the white component into the ratio of the red, green and blue components of the original image to drive each RGBW sub-pixel.

In the liquid crystal display apparatus according to the invention, the chromaticity of halftones of the original image will not change even when a white component

is added to each component of red, blue and green colors of the original image to improve the luminance, thus the above object being achieved.

These and other aspects of the invention are apparent from and will be elucidated with reference to embodiments described hereinafter with reference to the accompanying drawings, in which:

Fig. 1 is a block diagram showing the constitution of a liquid crystal display apparatus 100 according to a preferred embodiment of the invention;

Fig. 2 is a top plane view of the liquid crystal panel 1 of Fig. 1, in which the arrangement of sub-pixels, gate buses and source buses are illustrated;

Fig. 3 is a block diagram schematically illustrating a source driver 3 and a decoder 6 shown in Fig.1;

Fig. 4 is an illustration which explains the function of the preferred embodiment; and

Fig. 5 is a graph which explains a modification of the embodiment.

These Figures are diagrammatic and not to scale, and wherein corresponding components are generally denoted by the same reference numbers.

A preferred embodiment of a liquid crystal display apparatus according to the invention will now be described.

Fig. 1 is a block diagram showing the constitution of a liquid crystal display apparatus 100 according to an embodiment of the invention. This liquid crystal display apparatus 100 is provided with a liquid crystal panel 1.

Fig. 2 is a top plane view of this liquid crystal panel 1 in which a horizontal cross-section of the panel is schematically shown.

This liquid crystal panel 1 is provided with gate buses G1 to Gm (m: a natural number) each extending in a row direction and source buses S1 to Sn (n: a natural number) each extending in a column direction as shown in Fig. 2. The gate buses G1 to Gm are connected to a gate driver 2, and the source buses S1 to Sn are connected to source drivers 3.

A sub-pixel Lij of R (red), G (green), B (blue) or W (white) is disposed within each area defined by the gate buses Gi and G1+1 (i = 1 to m) and the source buses Sj and Sj+1 (j = 1 to m).

A TFT (thin film transistor) Qij is arranged in the vicinity of each intersection of the gate bus Gi and the source bus Sj.

Furthermore, the gate bus Gi is connected to a gate of the TFT Qij, the source bus Sj to a source of the TFTQij, and a display electrode of the sub-pixel Lij to a drain of the TFT Qij.

Opposed to the display electrode of each sub-pixel Lij is a common electrode which is connected to a common voltage supply circuit (not shown).

When the sub-pixels are arranged in the form of vertical stripes as shown in Fig. 2, color filters for RGBW are arranged in the following manner with respect to each sub-pixel Lij, wherein one pixel is constituted by four sub-pixels of RGBW.

R:Lij (i=1, 2, 3, ..., m-1; j=1, 5, 9, ..., n-3)

G:Lij (i=1, 2, 3, ..., m; j=2, 6, 10, ..., n-2)

B:Lij (i=1, 2, 3, ..., m; j=3, 7, 11, ..., n-1)

W:Lij (I=1, 2, 3, ..., m-1; j=4, 8, 12, ..., n)

In this liquid crystal panel 1, a TFT substrate (not shown) on which the sub-pixel electrodes are formed, a color filter substrate on which the common electrode is formed and a glass substrate or the like are arranged in a direction perpendicular to a surface of the panel and a liquid crystal is filled in a space between the substrates.

The description of the liquid crystal display apparatus 100 will be continued with reference to Fig.1 again.

The gate driver 2 and the eight source drivers 3 are arranged around the liquid crystal panel 1. Each source driver 3 comprises amplifiers, DACs (DA converters) and latches, all of which are not shown. A decoder 6 is connected to the eight source drivers 3. This decoder 6 is connected to an image data holding section 5 for converting an input signal to digital data, and receives therefrom eight-bit sub-pixel data of the acquired image.

This liquid crystal display apparatus 100 further comprises a signal control section 4. This signal control section 4 feeds a power supply voltage to the gate driver 2 and the source drivers 3, and supplies control signals to the gate driver 2 and the source drivers 3.

The liquid crystal display apparatus100 also comprises a reference potential generating circuit (not shown) for applying a reference potential to each source driver 3.

The operation of the liquid crystal display apparatus100 shown in Fig. 1 will be described below.

The control signals are supplied from the signal control section 4 to the gate driver 2 and the respective source drivers 3. The gate driver 2 transmits, based on the control

signal, to the respective gate buses (refer to Fig. 2) signals for turning TFTs Qij into the on condition.

When the control signal is supplied to each source driver 3, a latch portion (not shown) of each source driver 3 latches, based on the above control signal, eight-bit sub-pixel data (hereinafter referred to as "sub-pixel output luminance data Ro, Go, Bo and Wo") which have been obtained by the decoder 6 as signals for RGBW sub-pixels by performing a predetermined calculation (described later) on the data of image data RGB (hereinafter referred to as "sub-pixel input data Ri, Gi, and Bi") constituting the digital image as held in the image data holding section 5.

The sub-pixel data latched in the latch portion are sequentially supplied to a DAC portion (not shown). The signal control section 4 also outputs a polarity control signal for controlling whether the DAC portion selects a potential from the positive polarity reference potential generated by the reference potential generating circuit or a potential from the negative polarity reference potential generated by the reference potential generating circuit. This polarity control signal is input to the DAC portion. The DAC portion selects, based on the input polarity control signal and the sub-pixel output luminance data, a potential from the potential generated by the reference potential generating circuit which corresponds to the RGBW sub-pixel output luminance data.

When a potential is thus selected in the DAC portion, the DAC portion divides a voltage of the selected reference potential by a resistance division into appropriate steps so as to obtain a desired gradation. Thereafter, the divided voltage is current-amplified by an amplifier (not shown) and transmitted to a corresponding one of the source buses S1 to Sn (refer to Fig. 2). When TFTs are rendered on by a signal transmitted to any one of the gate buses G1 to Gm, the signal transmitted to the source bus and representing the potential is transferred through the above TFT to the corresponding pixel electrode.

In this manner, a potential corresponding to the sub-pixel data is given to each sub-pixel electrode. Therefore, a voltage is applied to each portion of the liquid crystal layer which is sandwiched between the common electrode and a respective one of the sub-pixel electrodes, so that the liquid crystal layer is driven in accordance with the potentials applied to the respective sub-pixel electrodes, whereby an image is displayed on the liquid crystal panel 1 in accordance with the principle of additive color mixing.

A preferred embodiment of the calculation processing performed in the above-described decoder 6 will now be described with reference to Figs.3(a) and 3(b) and mathematical formulas (1) to (5).

As shown in Fig. 3(a), the decoder 6 has a function of receiving the sub-pixel input data Ri, Gi, and Bi from the image data holding section 5 (Fig. 1), obtaining from these data the luminance data Wo for the luminance-enhancing sub-pixel and the sub-pixel output luminance data Ro, Go, Bo and Wo by calculation, and outputting these data to the source driver 3. Alternatively, the decoder 6 may be arranged to receive the sub-pixel input data Ri, Gi, and Bi from the image data holding section 5, to convert the data into values in the luminance dimension and then to perform the calculation.

In general, there is a relationship $Y=kDig^{2.2}$ (k is a constant of proportion) between a digital value Dig (an digital input data) and luminance Y in a display for a computer. In the calculation processing according to the present embodiment, a calculation which will be described later can also be performed using this luminance dimension.

However, by the conversion into such luminance dimension an eight-bit digital signal will become a value of the order of 16 bits, and as a result, a circuit to be used will become more sophisticated and large, whereby the cost will be increased.

For this reason, the calculation may be performed on the digital value, as it is, without any conversion of the above dimension in order to simplify the circuit. Even if the calculation is simplified, the influence on the quality of the displayed image will not be so large as to cause any trouble, and the quality may be acceptable in the practical use. Moreover, various calculation formulas according to the invention described herein can be explained based on the same principles regardless of the dimension of each data of red, blue and green.

Accordingly, the digital input value would be used as it is for the sake of simplify in the following description of the embodiment.

The internal structure and the operation of the decoder 6 will be described with reference to Fig.3 (b).

The decoder 6 is provided with a comparator 7, a look-up table 8, a red calculating circuit 9, a blue calculating circuit 10 and a green calculating circuit 11 as shown in Fig. 3(b).

The comparator 7 receives sub-pixel input data Ri, Gi, and Bi from the image data holding section 5 and then compares magnitudes of the data values of Ri, Gi and Bi to one another. The comparator 7 then obtains the maximum and minimum values of the data values of Ri, Gi and Bi as its comparison results, and outputs the minimum value to the look-up table 8 as Yimin and outputs the maximum value to the red calculating circuit 9, the blue calculating circuit 10 and the green calculating circuit 11 as Yimax.

The look-up table 8 receives the above minimum value Yimin and converts it into luminance data Wo for the luminance-enhancing sub-pixel.

This conversion in the look-up table 8 is performed by using PROM in which calculation results of a function Wo = f(Ymin) for each value of a variable Yimin are stored in addresses for Yimin, wherein Yimin ranges from zero to 255 when each sub-pixel is expressed in 256-step gradation. Alternatively, this conversion may be performed using a calculating circuit.

On the other hand, each of the red calculating circuit 9, the blue calculating circuit 10 and the green calculating circuit 11 performs a calculation according to a respective one of the following formulas with a respective value of data of the Ri, Gi, and Bi, the Yimax value and the Wo value:

mathematical formula (1): Ro=Ri*(Wo+Yimax)/Yimax-Wo;

mathematical formula (2): Go=Gi*(Wo+Yimax)/Yimax-Wo; and

mathematical formula (3): Bo=Bi*(Wo+Yimax)/Yimax-Wo;

(hereinafter referred to simply as "the mathematical formula (1)", "the mathematical formula (2)", and "the mathematical formula (3)" , respectively) to thereby obtain a respective one of the sub-pixel output luminance data Ro, Go and Bo.

The decoder 6 then outputs these RGB sub-pixel output luminance data Ro, Go and Bo to the source drivers 3 together with Wo.

The above-described mathematical formula (1) is a formula obtained by modifying mathematical formula (4): Ri/Yimax=(Ro+Wo)/(Yimax+Wo) (hereinafter referred to simply as, "mathematical formula (4)").

More specifically, the mathematical formula (4) is a relational expression for the purpose that the ratio between the data values Ri, Gi and Bi can be made equal to the ratio between the values obtained by adding Wo to the respective data Ro, Go and Bo, when the sub-pixel output luminance data Ro, Go and Bo for the RGB sub-pixels are obtained by adding the sub-pixel output luminance data Wo for the W sub-pixel to the RGB sub-pixel input luminance data Ri, Gi, and Bi.

Similarly, the mathematical formula (2) is a formula obtained by modifying mathematical formula (5): Gi/Yimax= (Go+Wo)/(Yimax+Wo), and the mathematical formula (3) is a formula obtained by modifying

mathematical formula (6): Bi/Yimax = (Bo+Wo) /(Yimax+Wo),

(hereinafter referred to simply as "mathematical formula (5)", and "mathematical formula (6)", respectively).

For the chromaticity of the image which is formed by the liquid crystal panel 1, the following effects can be obtained by driving the source drivers 3 with the RGB sub-pixel output luminance data Ro, Go and Bo and the sub-pixel output luminance data Wo for the W sub-pixels which have been obtained by the above mathematical formulas 1 to 3.

For example, when the above function Wo = f(Ymin) is represented by mathematical formula (7): Wo=Yimin
(hereinafter referred to simply as, "mathematical formula (7)"), the minimum value of Ri, Gi and Bi is selected as the value Wo. As a result, when at least one of the values Ri, Gi and Bi is zero, Wo = 0 is established.

In this case, Ro = Ri, Go = Gi and Bo = Bi are obtained according to the mathematical formulas (1) to (3). Accordingly, the chromaticity does not change in this case.

Moreover, according to the mathematical formulas (1) to (3), the ratio between the data values Ri, Gi and Bi is equal to the ratio between the values obtained by adding Wo to the respective data Ro, Go and Bo, so that the ratio between the colors does not change, as a result the chromaticity does not change even in the halftones.

As a specific example, the embodiment (an example of operation) of the decoder 6 will be described for the case of Ri=240, Gi=160 and Bi=120 with reference to Fig. 4.

First, the comparator 7 receives Ri = 240, Gi = 160, and Bi = 120 as its input data from the image data holding section 6 and determines from Ri = 240, Gi = 160 and Bi = 120 that the minimum value is 120 and the maximum value is 240, with the result that Yimin = 120, Yimax = 240.

The look-up table 8 determines Yimin = 120, which is output from the comparator 7, to be Wo value (here, the case where the value Wo = f(Yimin) is represented by the mathematical formula (7) is taken as an example).

Finally, the values of Yimin=120 and Yimax=240 and Wo=120 output from the comparator 7 and the look-up table 8, and the values of the RGB sub-pixel input luminance data Ri=240, Gi=160, and Bi=120 are substituted into the mathematical formulas 1 to 3 by the calculating circuits 9 to 11, respectively, whereby the RGBW sub-pixel output luminance data Ro=360, Go=240 and Bo=180 are obtained (refer to Fig. 4(c)).

As is apparent from this result, according to the calculations by the mathematical formulas 1 to 4, Ri:Gi:Bi=240:160:120=6:4:3 are obtained and Ro: Go:Ro=360:240:180=6:4:3 are obtained. Thus, it will be understood that the relation of Ri:Gi:Bi=Ro:Go:Ro is satisfied.

Since the ratio of RGB of the output luminance data will not differ from the ratio of RGB of the input data even when Wo is added in order to improve luminance, the chromaticity (color saturation) of the halftones will not be degraded. It is needless to say that the relation represented by the mathematical formulas (4) to (6) is also satisfied even in the case where the digital value of each variable is converted into the dimension of luminance for the reason mentioned above.

More specifically, when the digital value Ri, Gi, and Bi for the red input sub-pixel, the green input sub-pixel and the blue input sub-pixel obtained from the input image are converted into RI, GI and BI as the values having the dimension of luminance, and the luminance values for the red output sub-pixel, the green output sub-pixel, the blue output sub-pixel and the luminance-enhancing sub-pixel are represented as RO, G0, BO and WO, the relation of RI:GI:BI=1 (RO+WO):(GO+WO):(BO+WO) will be satisfied.

Furthermore, various kinds of modifications can be adopted to the above-described preferred embodiment. Such modifications will now be described.

In the preferred embodiment, although output luminance data for sub-pixel Wo is defined as the value obtained by the function in which the minimum value Yimin of input data for RGB sub-pixel Ri, Gi, and Bi is taken as a variable, a value which is obtained by other functions in accordance with the target optical characteristic (luminance) may also be selected as Wo.

(1) For example, a Wo value which is obtained by a calculating formula represented by Wo=f(Ymin,Ymax) as a function which is monotonously increased as each of these two values Ymin and Ymax increases, or as a function which is monotonously increased as the minimum value Ymin increases with the maximum value Ymax being a constant may also be selected as the function, when the maximum value and the minimum value of the input data Ri, Gi, and Bi for the RGB sub-pixels are Ymax and Ymin, respectively.

(2) When it is desired to emphasize white of maximum luminance, a Wo value which is obtained by a function such as mathematical formula (8): $Wo=255*(Yimin/255)^2$ may also be selected.

(3) When it is desired to brighten the halftones, a Wo value which is obtained by a function such as mathematical formula (9): $Wo=-Yimin^3/255^2+Yimin^2/255+Ymin$ can also be selected.

In the mathematical formulas (8) and (9), Yimin is the minimum value of input luminance data for RGB sub-pixels Ri, Gi, and Bi as in the preferred embodiment.

However, when a Wo value is selected, limits should be defined as will be described below, while satisfying the condition that the ratio between the colors is maintained.

When the maximum value and the minimum value of the input data are Ymax and Ymin, and the maximum value and the minimum value of the output luminance data are Yomax and Yomin, a formula Ymin/Ymax= (Yomin+Wo)/(Yomax+Wo)should be established in order to maintain the ratio between the respective colors, where Yomax=Ymax.

Since the sub-pixel for luminance is added in order to increase luminance, it is desirable that the value of Wo which is given thereto is as large as possible.

To give a value as large as possible to Wo means to replace all the white components in the output data with Wo, with Yomin=0, the formula described above can be modified into Ymin/Ymax=Wo/(Ymax+Wo).

When solving this formula with respect to Wo, the following formula can be obtained: Wo=Ymin*Ymax/(Ymax-Ymin).

In this formula, it is understood that Wo>Ymax can be obtained when Ymin/Ymax>0.5. When Ymax is the maximum value which can be taken (for example, 255 gradation level in the case of eight bits), Wo satisfying Wo>Ymax does not exist.

Therefore, Wo=Ymax is established when Ymin/Ymax>0.5.

In summary, the ratio between the respective colors can be maintained by selecting an optional function so as to satisfy the following relation in order to determine Wo.

When Ymin/Ymax <= 0.5, a formula Wo <= Ymin*Ymax/(Ymax-Ymin) can be obtained.

When Ymin/Ymax > 0.5, a formula Wo <= Ymax can be obtained.

Although Wo is represented as a function of Ymin and Ymax, since an area of Wo becomes narrower as Ymax becomes larger, the range in which an arbitrary Ymax can be applied is as shown by hatching in Fig. 5. That is to say, this hatched area is the range of values of Wo which can be added for improving luminance while satisfying the condition that the ratio between the respective colors is maintained.

As described above, according to the liquid crystal display device of the invention, the luminance can be improved appropriately without changing the chromaticity of halftones, even when the luminance of the image displayed on the liquid crystal panel is attempted to be enhanced by the white sub-pixels for increasing luminance.

CLAIMS:

1. A liquid crystal displaying apparatus capable of displaying a color image comprising a liquid crystal panel in which each main pixel unit including a red sub-pixel, a green sub-pixel, a blue sub-pixel and a luminance-enhancing sub-pixel characterized by comprising:

calculation means for calculating digital output values Ro, Go and Bo for driving said red sub-pixel, said green sub-pixel and said blue sub-pixel, respectively, from digital input values Ri, Gi and Bi respectively for said red sub-pixel, said green sub-pixel and said blue sub-pixel and a predetermined digital value W for driving said luminance-enhancing sub-pixel so that a relationship of Ri:Gi:Bi = (Ro+W):(Go+W):(Bo+W) is satisfied, said values Ri, Gi and Bi being obtained from an input color image.

2. A liquid crystal displaying apparatus according to claim 1 characterized in that said digital value W is obtained in accordance with a function represented by a formula W = f(Ymin) where Ymin is a minimum value of said digital input values for said red sub-pixel, said green sub-pixel and said blue sub-pixel.

3. A liquid crystal displaying apparatus according to claim 1 characterized in that said digital value W is obtained in accordance with a function represented by a formula W = f(Ymax, Ymin) where Ymax and Ymin are a maximum value and a minimum value, respectively, of said digital input values for said red sub-pixel, said green sub-pixel and said blue sub-pixel.

4. A liquid crystal displaying apparatus according to claim 3 characterized in that said function represented by said formula W = f(Ymax, Ymin) is a function which monotonously increases as a value of said Ymax value or said Ymin value becomes larger.

5. A liquid crystal displaying apparatus according to claim 3 characterized in that said formula of W is given by a function in which said Ymin is a variable with said Ymax

being a constant and in that said function represented by said formula W = f(Ymax, Ymin) is a function which monotonously increases as a value of said Ymin becomes larger.

6. A liquid crystal displaying apparatus according to any one of claims 1 to 5 characterized in that said digital input values Ri, Gi and Bi for said red, green and blue sub-pixels obtained from said input color image are converted respectively into RI, GI and BI as values having a dimension of luminance, and in that a relationship of RI:GI:BI = (RO+WO):(GO+WO):(BO+WO) is satisfied when luminance values for said red sub-pixel, said green sub-pixel, said blue sub-pixel and said luminance-enhancing sub-pixel are represented by RO, GO, BO and WO, respectively.

ABSTRACT:

In an RGBW-type liquid crystal display device, luminance is improved by the addition of W sub-pixels while an image is displayed without any change in chromaticity of halftones. Digital corrected values for red, green and blue are obtained by adding a predetermined digital value for driving a W sub-pixel to each of RGB digital values which correspond respectively to pixels of an acquired image. A converting calculation is effected on the digital corrected values such that the ratio of these digital corrected values for red, green and blue is made equal to the ratio of the red, green and blue digital values corresponding to the pixels of said acquired image. The RGBW sub-pixels are driven with the converted values and the predetermined digital value for driving W sub-pixel to thereby display an image.

Fig.3

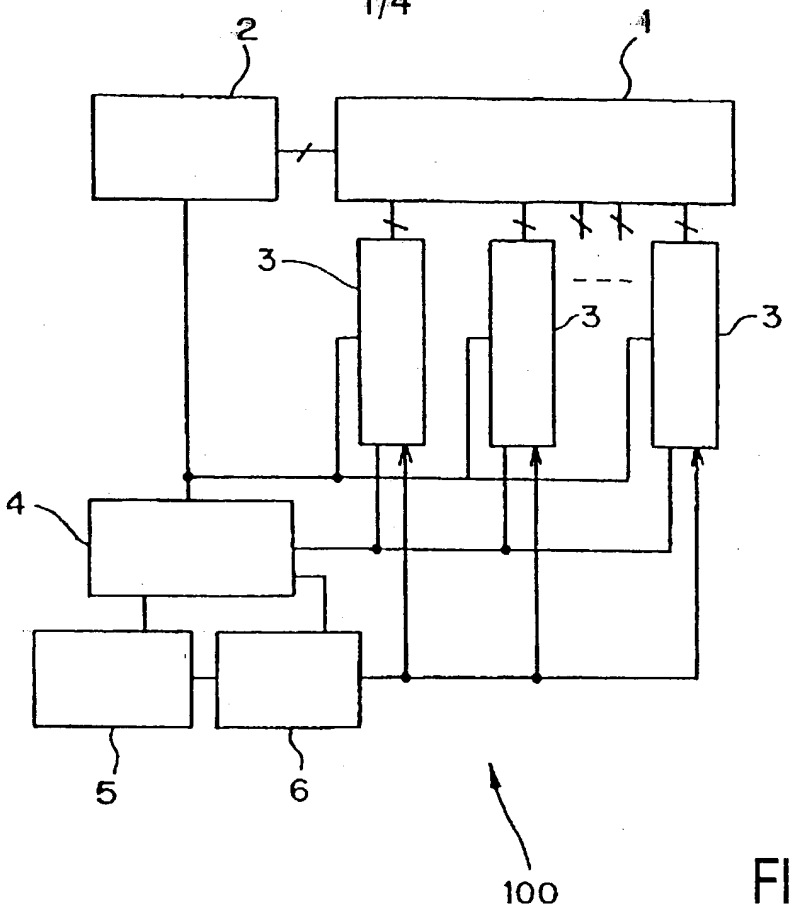
2
1
3
3
3
4
5
6
100

FIG. 1

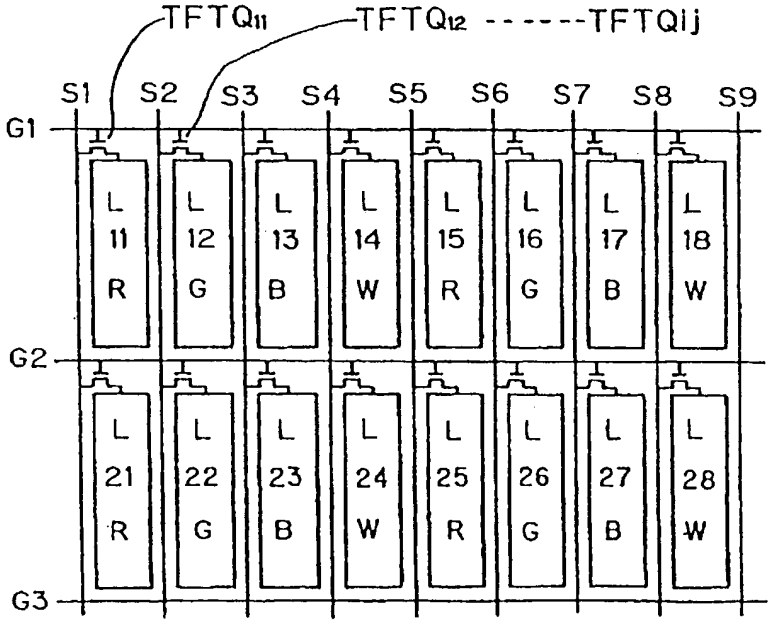
TFTQ11
TFTQ12 ------TFTQIj
S1
S2
S3
S4
S5
S6
S7
S8
S9
G1
G2
G3
L 11 R
L 12 G
L 13 B
L 14 W
L 15 R
L 16 G
L 17 B
L 18 W
L 21 R
L 22 G
L 23 B
L 24 W
L 25 R
L 26 G
L 27 B
L 28 W

FIG. 2

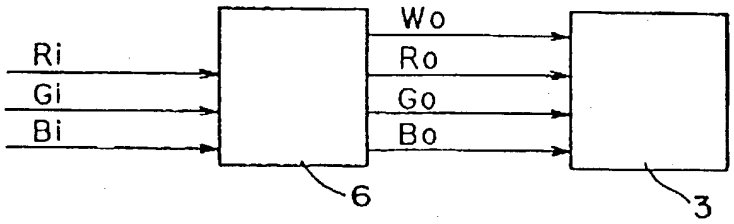
Ri
Gi
Bi
Wo
Ro
Go
Bo
6
3

FIG. 3a

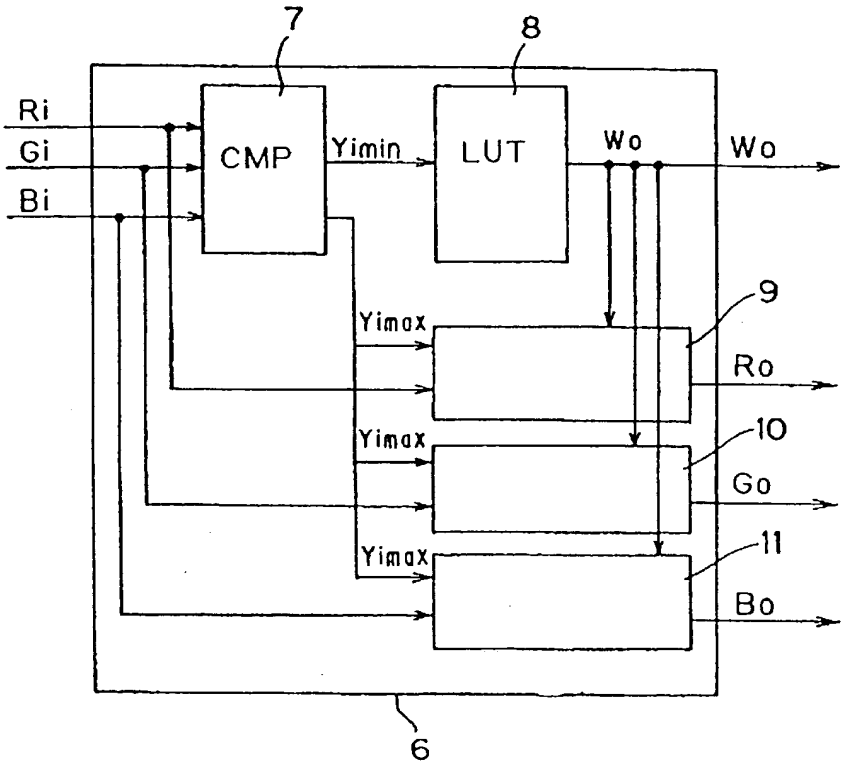
7
8
Ri
Gi
Bi
CMP
Yimin
LUT
Wo
Wo
9
Yimax
Ro
10
Yimax
Go
11
Yimax
Bo
6

FIG. 3b

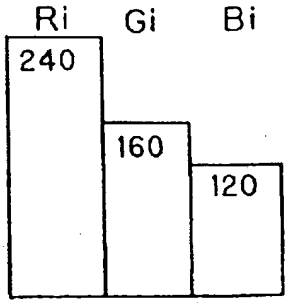

FIG. 4a

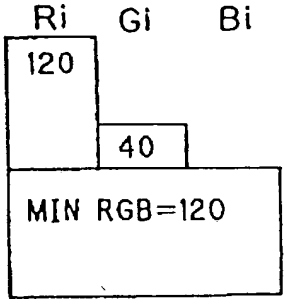

FIG. 4b

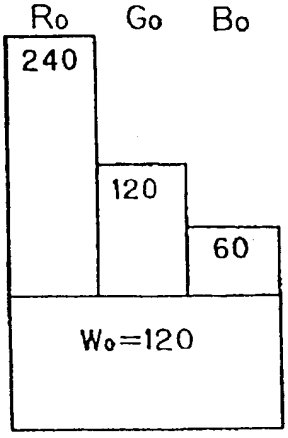

FIG. 4c

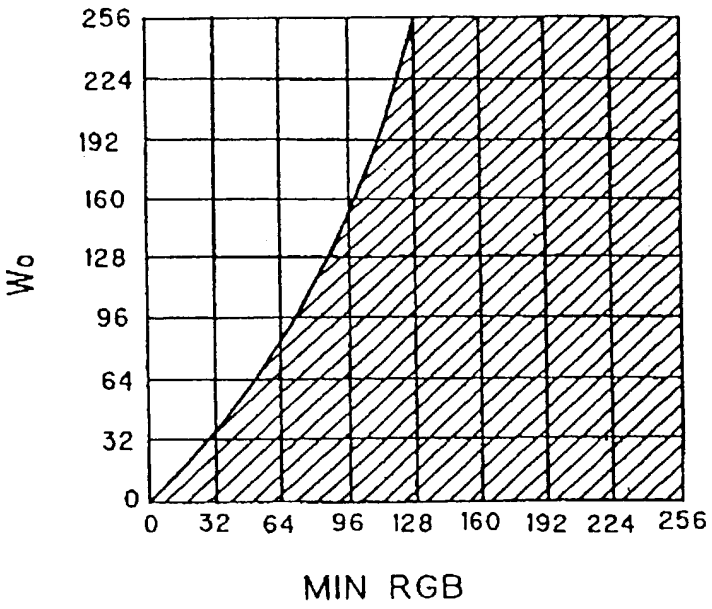
256
224
192
160
128
96
64
32
0
W_o
0
32
64
96
128
160
192
224
256
MIN RGB

FIG. 5

09889090 .062602

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (includes Reference to PCT International Applications)	ATTORNEY'S DOCKET NUMBER **PHJ 99.024 US**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **"Liquid crystal display apparatus"** the specification of which (check only one item below):

☐ is attached hereto.

☐ was filed as United States application

Serial No _____

on _____

and was amended

on _____

☒ was filed as PCT international application

Number PCT/EP00/11250

on 10 November 2000

and was amended under PCT Article 19

on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY	APPLICATION NUMBER	DATE OF FILING DAY, MONTH, YEAR	PRIORITY CLAIMED UNDER 35 USC 119
Japan	**321,901/99**	**12 November 1999**	**YES**

09889090 .062602

Combined Declaration For Patent Application and Power of Attorney (Continued) (includes Reference to PCT International Applications)	Attorneys Docket Number **PHJ 99.024 US**

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) abnd/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (List name and registration number)

Jack E. Haken, Reg. No. 26,902 Michael E. Marion, Reg. No. 32, 66 Edward M. Blocker, Reg. No. 30,245	Direct Telephone Calls to: (name and telephone number) (914)332-0222

1-00 201	FULL NAME OF INVENTOR	FAMILY NAME **HIRANO**	FIRST GIVEN NAME **Satoshi**	SECOND GIVEN NAME
	RESIDENCE & CITIZENSHIP	CITY **Itabashiku** JPX	STATE OR FOREIGN COUNTRY **Japan**	COUNTRY OF CITIZENSHIP **Japan**
	POST OFFICE ADDRESS	POST OFFICE ADDRESS **3-32-10-906 Akatsuka-Shinmachi**	CITY **Itabashi-ku, Tokyo**	STATE & ZIP CODE/COUNTRY **Japan**
2-00 202	FULL NAME OF INVENTOR	FAMILY NAME **YASUI**	FIRST GIVEN NAME **Masaru**	SECOND GIVEN NAME
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	POST OFFICE ADDRESS	POST OFFICE ADDRESS **4-20-3 Karibadai**	CITY **Nishi-ku, Kobe-city, Hyogo Prefecture**	STATE & ZIP CODE/COUNTRY **Japan**
203	FULL NAME OF INVENTOR	FAMILY NAME **KAMIYA (DECEASED)**	FIRST GIVEN NAME **Takeo**	SECOND GIVEN NAME
	RESIDENCE & CITIZENSHIP	CITY **Nishi-ku, Kobe-city**	STATE OR FOREIGN COUNTRY **Japan** JPX	COUNTRY OF CITIZENSHIP **Japan**
	POST OFFICE ADDRESS	POST OFFICE ADDRESS **4-3-1 Takatsukadai**	CITY **Nishi-ku, Kobe-city, Hyogo Prefecture**	STATE & ZIP CODE/COUNTRY **Japan**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true: and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 if Title 18 of the United states Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

SIGNATURE OF INVENTOR 201	SIGNATURE OF INVENTOR 202	SIGNATURE OF INVENTOR 203 **Legal Representative**
Satoshi Hirano	Masaru Yasui	Akihiko Miyazaki Akihiko MIYAZAKI
DATE 4 April 2001	DATE 4 April 2001	DATE 18 April 2001

Registered No. 136 (in 2001)

NOTARIAL CERTIFICATE

This is to certify that Mr. Akira Kamiya has affixed his signature in my very presence to the attached document.

Dated this 18 day of April 2001.

Hidetoshi Koura

Notary, attached to

Nagoya Legal Affairs Bureau.

No. 17-29 1-chome Meieki Minami Nakamuraku,

Nagoya, Japan.

HIDETOSHI KOURA
NOTARY
NAGOYA LEGAL AFFAIRS BUREAU
MINISTRY OF JUSTICE
NO.17-29 1-CHOME MEIEKI MINAMI
NAGOYA.JAPAN

DECLARATION AND POWER OF ATTORNEY
Deceased Inventor

Attorney's Docket No. PHJ 99.024

As legal representative of the below-named deceased inventor, I hereby declare that:
The last residence, post office address and citizenship of the deceased inventor are as stated below.
My residence, post office address and citizenship are as stated below next to my name.
I believe that the below-named deceased inventor is the original, first and sole inventor or is an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled LIQUID CRYSTAL DISPLAY APPARATUS

the specification of which (check one)

is attached hereto.

_X_ was filed on July 11, 2001 as Application Serial No. 09/889,090 and was amended on _____.
And was filed as PCT international application number PCT/EP00/11250 on November 10, 2000.

I hereby state that I have reviewed the contents of the above-identified specification, including the claims, as amended by any amendment referred to above, and on information and belief understand the same.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

COUNTRY	APPLICATION NO.	DATE OF FILING	PRIORITY Claimed Under U.S.C. 119
Japan	321,901/99	12 November 1999	Yes

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56(a) which occurred between the filing date of the prior application and the national or PCT International filing date of this application:

PRIOR UNITED STATES APPLICATION(S)

APPLICATION SERIAL NO.	FILING DATE	STATUS (PATENTED/PENDING/ABANDONED)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As legal representative of the named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.(list name/reg. no.)

Michael E. Marion, Reg. No. 32,266
Jack E. Haken, Reg. No. 26,902
Edward Blocker, Reg. No. 30,245

SEND CORRESPONDENCE TO: Corporate Intellectual Property Counsel
U.S. Philips Corporation
580 White Plains Road
Tarrytown, New York 10591

DIRECT TELEPHONE CALLS TO:
Eric M. Bram (914) 333-9635

DECEASED INVENTOR

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SOLE HEIR and LEGAL REPRESENTATIVE

Relationship to the deceased: The undersigned, Akira Kamiya, states that he is the legal representative of the deceased by virtue of being the father and sole heir of the deceased.

DATED: June 19, 2002

LEGAL REPRESENTATIVE'S SIGNATURE: Akira Kamiya

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FULL NAME OF INVENTOR: Yasui (Last Name) Masaki (First Name) (Middle Name)

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Japan (State or Country) (Zip Code)

[redacted]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of Atty. Docket

HIRANO ET AL PHJ 99-024

Serial No. Group Art Unit

Filed: CONCURRENTLY Ex.

LIQUID CRYSTAL DISPLAY APPARATUS

Honorable Commissioner for Patents
Washington, D.C. 20231

APPOINTMENT OF ASSOCIATES

Sir:

The undersigned Attorney of Record hereby revokes all prior appointments (if any) of Associate Attorney(s) or Agent(s) in the above-captioned case and appoints:

Eric M. Bram (Registration No. 37,285)

(Registration No.) and

c/o U.S. PHILIPS CORPORATION, Intellectual Property Department, 580 White Plains Road, Tarrytown, New York 10591, his Associate Attorney(s)/Agent(s) with all the usual powers to prosecute the above-identified application and any division or continuation thereof, to make alterations and amendments therein, and to transact all business in the Patent and Trademark Office connected therewith.

ALL CORRESPONDENCE CONCERNING THIS APPLICATION AND THE LETTERS PATENT WHEN GRANTED SHOULD BE ADDRESSED TO THE UNDERSIGNED ATTORNEY OF RECORD.

Respectfully,

Jack E. Haken, Reg. 26,902
Attorney of Record

Dated at Tarrytown, New York
this July 10, 2001

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